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Antennal sensilla of the rice hispa *Dicladispa armigera* (Olivier, 1808) (Coleoptera: Chrysomelidae)

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Abstract. Number and types of sensilla on each antennal segment of male and female adult rice hispa *Dicladispa armigera* (Olivier) (Coleoptera: Chrysomelidae) were determined based on light and scanning electron microscopic observations. The males had a significantly greater total number (o 1828.11) of sensilla than females (ø 1764.43). Five types of sensilla, namely, sensilla chaetica, sensilla trichodea I, sensilla trichodea II, sensilla basiconica and pit or coeloconic sensilla were distinguished in both sexes. Sensilla trichodea I and II were distributed over the entire length of the antenna, whereas sensilla chaetica were observed only on the apical five flagellomeres. Methoprene affected antennal morphology by producing two-clubbed antenna (additional one at the 3rd flagellomere) and alteration in the sensilla of the last flagellomere.

Key words. Rice hispa, sensilla chaetica, sensilla trichodea I, sensilla trichodea II, sensilla basiconica, methoprene.

INTRODUCTION

The rice hispa *Dicladispa armigera* (Olivier, 1808) (Coleoptera: Chrysomelidae) occurs in South East Asia and Africa, and is one of the major pests of rice in many rice growing states of India (Deka & Hazarika 1996; Palaszek et al. 2002; Islam et al. 2004; Hazarika et al. 2005). It causes considerable damage to vegetative stages of rice resulting in yield loss of 28% in India (Nath & Dutta 1997), between 20–30% in Nepal (Dhaliwal et al. 1998) and up to 52% in deepwater rice in Bangladesh (Islam 1989); however, it may be as high as 100% in the rice transplanted post flood in Assam (Hazarika 2005). In order to manage this pest, attempts were made to identify pheromones in this insect, with mixed results (Deka & Hazarika 1997). Pheromones are not only used for survey and surveillance of insect pest but also used to manage them.

During the last three decades, insect communication through antennal sensilla has received substantial interest (Rao et al. 1990; Kumar et al. 1995; Axtell 1999). Generally, antennae are covered with huge numbers of sensilla, relevant as sensory organs (Chapman 1982). Antennal sensilla are involved in host recognition and mate or microhabitat choice by pheromone- thermo- and hygroreception (Hazarika & Bardoloi 1998; Chen et al. 2003; Ploomi et al. 2003; Marttje et al. 2004). A number of studies has been conducted on the sensilla of other coleopteran insects like flea beetles, *Phyllotetra cruciferae* (Goeze, 1777), *Psylliodes punctulata* Melsheimer, 1847, *P. affinis* (Paykull, 1799) and *Epitrix cucumeris* (Harris, 1851) (Ritcey & McIver 1990); however, currently there is no information available describing the sensilla of the rice hispa. Accordingly, the present study was undertaken in order to determine the number and types of sensilla on each antennal segment of male and female adults of *D. armigera*.

MATERIALS AND METHODS

For determination of number of sensilla, male and female antennae of field collected adults were fixed separately in carnoy-lebrun fixative for 30 min and washed for 10 minutes in each of the 30%, 50% and 70% alcohol. The antennae were then allowed to remain for twenty minutes in each of the 90% and absolute alcohol, after which they were again passed through xylene and cleared in clove oil. These were then mounted in DPX. Sensilla were observed under the compound microscope at 100X, 400X and 1000X magnification in oil and were counted on each segment following the method of Ramaswamy & Gupta (1981).

Table 1. Estimated number (Mean±S.E.) of sensilla on each antennal segment of adult male and female *D. armigera*.

Segment	Male	Female	t-value
Scape	25.25 ± 0.29^{i}	21.23 ± 0.37^{i}	8.95**
Pedicel	28.45 ± 0.32^{h}	24.99 ± 0.28^{h}	8.77**
Flagellum (Fl)			
Fl 1	19.28 ± 0.25^{k}	18.02 ± 0.29^{j}	2.95**
Fl 2	22.48 ± 0.30^{j}	21.48 ± 0.30^{i}	2.48*
Fl 3	33.66 ± 0.32^{g}	26.69 ± 0.30^{g}	15.15**
Fl 4	61.67 ± 0.65^{f}	56.77 ± 0.38^{f}	6.82**
Fl 5	220.43 ± 0.34^{e}	223.25 ± 0.35^{e}	-6.53**
Fl 6	265.20 ± 0.41^{d}	258.36 ± 0.49^{d}	9.79**
Fl 7	302.26 ± 0.33^{c}	295.73 ± 0.40^{c}	11.99**
Fl 8	336.11 ± 0.28^{b}	332.84 ± 0.39^{b}	8.15**
Fl 9	490.84 ± 0.53^{a}	485.07 ± 0.46^{a}	7.47**
S.Ed. (±)	0.05	0.52	
C.D. $_{0.05}$	0.11	1.04	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

For determination of types of sensilla, the antennae were fixed for six hours in carnoy-lebrun fixative and mounted in DPX (Schafer & Sanchez 1976). Based on the morphology of the sensilla, sensilla were classified into types. Sizes of these sensilla were measured with the ocular micrometer and readings were converted into µm. We also bleached the antennae in 2% hydrogen peroxide for 24 hr. Permeable areas of antennae were examined under bright field illumination using crystal violet method (Slifer 1960). One hundred 6–12 h old pupae were treated with 5 ppm methoprene (Altosid SE, 62.5% RS methoprene, Zoecon, Palo Alto, CA). Twenty adultoids were randomly selected for this study.

Scanning electron microscopy studies of the antennae of the adults and adultoids were undertaken by following the method described in Hazarika & Bardoloi (1998). Antennae were dissected out of the head and cleaned in distilled water, which were then fixed in buffered glutaraldehyde. They were dehydrated by passing through a series of acetone starting from 30% to 100%. On drying, antennae were placed on stubs using double sided, scotch tapes and coated with gold-palladium in a sputterer (JEOL, JFC 1100, Japan) for 5–10 min. The specimens were scanned in a scanning electron microscope (JEOL, 35-CF, Japan) at 15 KV and photographs were taken for each of the specimens.

RESULTS

The clubbed antennae of adult specimens consisted of scape, pedicel and nine sub-segmented flagellum, each sub-segment is called flagellomere, the first flagellomere being the longest (0.30±0.02 mm) while eighth is the shortest (0.15±0.02 mm). A spine is present on the ventral surface of the scape though the rest of the antenna is free from such spines. Scanning electron microscopic studies revealed the presence of scales on the scape, pedicel and first to sixth flagellomere. The numbers of sensilla in male and female adults of *D. armigera* are shown in Tab. 1. In male and female antennae, the distal segments are densely covered with sensilla. There is a distinct difference in shape of the 9th flagellomere between the male and female. In each segment as well as sub-segments, the male adults had a significantly greater number of sensilla than its female counterpart (Tab. 1) except on the fifth flagellomere, where it was reverse.

The mean number of sensilla per unit area is shown in Tab. 2. Both in male and female, the maximum population was observed on the eighth and ninth flagellomere (7.11±0.03 mm^2 and 8.89±0.03 mm^2, respectively) and the lowest was observed on the scape (0.37±0.01 mm^2 and 0.29±0.01 mm^2, respectively). Though density of sensilla on each segment was significantly higher in the male, but on the fifth to ninth flagellomere, it was reverse (Tab. 2).

Table 2. Mean±S.E. density of sensilla (number/mm^2) on each antennal segment of adult male and female *D. armigera*.

Segment	Male	Female	t-value
Scape	0.37 ± 0.01^{i}	0.29 ± 0.01^{j}	10.28^{**}
Pedicel	0.60 ± 0.01^{h}	0.48 ± 0.01^{i}	9.45^{**}
Flagellum (Fl)			
Fl 1	0.42 ± 0.01^{i}	0.35 ± 0.01^{j}	4.35^{**}
Fl 2	0.63 ± 0.02^{h}	0.57 ± 0.01^{h}	2.80^{*}
Fl 3	0.96 ± 0.01^{g}	0.81 ± 0.01^{g}	7.77^{**}
Fl 4	2.03 ± 0.02^{f}	2.09 ± 0.03^{f}	-1.94^{NS}
Fl 5	4.49 ± 0.02^{f}	5.26 ± 0.02^{e}	-26.47^{**}
Fl 6	5.98 ± 0.16^{d}	6.30 ± 0.04^{d}	-1.89^{NS}
Fl 7	6.15 ± 0.02^{c}	7.65 ± 0.03^{c}	-48.52^{**}
Fl 8	6.95 ± 0.03^{b}	7.75 ± 0.03^{b}	-17.18^{**}
Fl 9	7.11 ± 0.03^{a}	8.89 ± 0.03^{a}	-42.61^{**}
S.Ed. (±)	0.07	0.03	
C.D. $_{0.05}$	0.14	0.07	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $P < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 3. Size (Mean±S.E., length x width in µm) of sensilla trichodea I on each antennal segment of adult male and female *D. armigera*.

Segment	Male		Female		t-value	
					Length	Width
Scape	41.46 ± 0.03^{a} x 1.86 ± 0.02^{cd}		39.52 ± 0.04^{a} x 1.83 ± 0.02^{cd}		41.07^{**}	-2.27^{*}
Pedicel	39.23 ± 0.08^{b} x 1.80 ± 0.01^{d}		38.50 ± 0.07^{c} x 1.74 ± 0.02^{e}		13.70^{**}	2.46^{*}
Flagellum (Fl)						
Fl 1	36.50 ± 0.09^{h} x 1.74 ± 0.02^{e}		36.56 ± 0.05^{f} x 1.74 ± 0.02^{e}		-0.53^{NS}	0.01^{NS}
Fl 2	37.18 ± 0.07^{g} x 1.81 ± 0.01^{cd}		35.21 ± 0.05^{i} x 1.81 ± 0.01^{d}		32.91^{**}	0.42^{NS}
Fl 3	37.46 ± 0.07^{f} x 1.84 ± 0.02^{cd}		35.80 ± 0.03^{h} x 1.83 ± 0.02^{cd}		23.55^{**}	0.15^{NS}
Fl 4	37.84 ± 0.12^{e} x 1.81 ± 0.01^{cd}		36.37 ± 0.16^{g} x 1.84 ± 0.02^{cd}		9.53^{**}	-1.08^{NS}
Fl 5	37.87 ± 0.18^{e} x 1.85 ± 0.01^{c}		38.00 ± 0.05^{e} x 1.86 ± 0.02^{bc}		-0.70^{NS}	-0.55^{NS}
Fl 6	38.00 ± 0.07^{de} x 1.89 ± 0.01^{b}		38.10 ± 0.04^{de} x 1.90 ± 0.02^{ab}		1.91^{NS}	0.31^{NS}
Fl 7	38.22 ± 0.06^{de} x 1.90 ± 0.02^{b}		38.22 ± 0.04^{cd} x 1.89 ± 0.01^{ab}		0.01^{NS}	0.41^{NS}
Fl 8	38.51 ± 0.06^{c} x 1.92 ± 0.02^{b}		38.52 ± 0.04^{b} x 1.99 ± 0.01^{ab}		26.17^{NS}	
0.82^{NS}						
Fl 9	38.54 ± 0.07^{c} x 1.96 ± 0.01^{a}		38.63 ± 0.03^{b} x 1.92 ± 0.01^{a}		24.52^{NS}	6.56^{**}
S.Ed. (±)	0.13	0.02	0.09	0.02		
C.D. $_{0.05}$	0.25	0.04	0.18	0.05		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 4. Estimated number (Mean±S.E.) of sensilla trichodea I on each antennal segment of adult male and female *D. armigera.*

Segment	Male	Female	t-value
Scape	2.51±0.37^{j}	1.88±0.42^{j}	1.29^{NS}
Pedicel	5.81±0.52^{hi}	5.50±0.50^{h}	0.46^{NS}
Flagellum (Fl)			
Fl 1	3.93±0.50^{ij}	3.45±0.21^{ij}	0.83^{NS}
Fl 2	6.44±0.48^{h}	5.02±0.47^{hi}	2.02^{NS}
Fl 3	12.72±0.62^{g}	7.69±0.58^{g}	7.61**
Fl 4	21.82±0.66^{f}	11.46±0.52^{f}	12.11**
Fl 5	141.77±0.66^{e}	137.22±0.82^{e}	3.96**
Fl 6	155.43±0.66^{d}	176.46±0.84^{d}	-16.56**
Fl 7	181.34±0.79^{c}	182.43±0.82^{c}	-1.13^{NS}
Fl 8	209.44±1.97^{b}	204.10±0.64^{b}	2.74^{NS}
Fl 9	235.03±0.69^{a}	198.29±0.76^{a}	31.57**
S.Ed. (±)	1.17	0.89	
C.D. $_{0.05}$	2.32	1.76	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$ probability level, respectively (Student t-test; t-values are shown against each pair; d.f. < 49).

Table 5. Size (Mean±S.E., length x width in µm) of sensilla trichodea II on each antennal segment of adult male and female *D. armigera..*

Segment	Male	Female	t-value	
			Length	Width
Scape	38.11±0.23^{a} x 1.73±0.01^{cd}	36.52±0.05^{a} x 1.70±0.03^{def}	6.77**	0.87^{NS}
Pedicel	36.52±0.09^{b} x 1.71±0.01^{de}	34.75±0.04^{b} x1.68±0.02^{ef}	20.00**	1.33^{NS}
Flagellum (Fl)				
Fl 1	30.03±0.05^{e} x 1.69 ±0.01^{e}	29.12±0.04^{f} x 1.67±0.01^{f}	11.60**	1.10^{NS}
Fl 2	31.45±0.01^{d} x 1.73±0.01^{cd}	31.04±0.06^{d} x 1.73±0.01^{de}	5.93**	0.31^{NS}
Fl 3	32.06±0.09^{c} x 1.72±0.01^{cd}	31.73±0.04^{e} x 1.74±0.01^{cd}	2.83*	-1.59^{NS}
Fl 4	32.15±0.10^{c} x 1.73±0.02^{cd}	30.04±0.04^{e} x 1.74±0.02^{cd}	22.25**	-0.46^{NS}
Fl 5	25.05±0.12^{i} x 1.73±0.01^{cd}	26.51±0.06^{h} x 1.78±0.02^{abc}	-8.97**	-1.64^{NS}
Fl 6	27.73±0.12^{g} x 1.75±0.01^{c}	26.83±0.07^{g} x 1.74±0.02^{bcd}	7.44**	-0.13^{NS}
Fl 7	28.24±0.05^{f} x 1.78±0.01^{b}	25.01±0.04^{i} x 1.78±0.01^{abc}	40.29**	-0.43^{NS}
Fl 8	26.17±0.07^{h} x 1.80±0.01^{b}	24.30±0.04^{j} x 1.79±0.01^{ab}	26.57**	1.75^{NS}
Fl 9	24.52±0.06^{j} x 1.87±0.01^{a}	24.04±0.03^{k} x 1.80±0.01^{a}	6.77**	8.11**
S.Ed. (±)	0.15 0.01	0.07 0.02		
C.D. $_{0.05}$	0.29 0.02	0.13 0.04		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 6. Estimated number (Mean±S.E.) of sensilla trichodea II on each antennal segment of adult male and female *D. armigera*

Segment	Male	Female	t-value
Scape	22.61±0.49^{f}	19.31±0.69^{g}	4.10**
Pedicel	22.92±0.56^{f}	19.63±0.59^{g}	4.27**
Flagellum (Fl)			
Fl 1	15.61±0.67^{h}	14.76±0.46^{h}	0.38^{NS}
Fl 2	16.01±0.55^{h}	16.33±0.53^{h}	-0.44^{NS}
Fl 3	20.10±0.53^{g}	20.10±0.62^{g}	-0.01^{NS}
Fl 4	39.88±0.61^{e}	45.37±0.74^{f}	-5.55**
Fl 5	63.90±0.61^{d}	64.68±0.66^{e}	-0.84^{NS}
Fl 6	73.66±0.61^{c}	70.81±0.62^{d}	-2.52*
Fl 7	83.21±0.62^{b}	79.10±0.70^{c}	3.28**
Fl 8	83.37±0.84^{b}	90.75±0.82^{b}	7.19**
Fl 9	136.75±0.77^{a}	156.84±0.73^{a}	-19.07**
S.Ed. (±)	0.89	0.93	
C.D. $_{0.05}$	1.76	1.84	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 7. Size (Mean±S.E., length x width in µm) of sensilla chaetica on each antennal segment of adult male and female *D. armigera.*

Segment	Male		Female		t-value	
					Length	Width
Scape	–		–		–	–
Pedicel	–		–		–	–
Flagellum (Fl)						
Fl 1	–		–		–	–
Fl 2	–		–		–	–
Fl 3	–		–		–	–
Fl 4	–		–		–	–
Fl 5	30.15±0.19^{e} x 2.70±0.02^{d}		32.24±0.05^{c} x 2.74±0.01^{d}		-22.17 **	-2.15 *
Fl 6	33.41±0.06^{d} x 2.86±0.02^{c}		32.99±0.05^{d} x 2.89±0.05^{c}		7.26 **	-0.64^{NS}
Fl 7	34.11±0.06^{c} x 2.94±0.02^{b}		33.50±0.04^{c} x 2.85±0.02^{c}		11.79 **	3.83 **
Fl 8	37.57±0.06^{b} x 3.00±0.03^{b}		38.40±0.04^{b} x 2.99±0.03^{b}		-11.92 **	0.28^{NS}
Fl 9	38.15±0.06^{a} x 3.12±0.02^{a}		38.70±0.03^{a} x 3.10±0.03^{a}		-6.67 **	0.67^{NS}
S.Ed. (±)	0.09	0.03	0.06	0.04		
C.D. $_{0.05}$	0.18	0.06	0.12	0.08		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 8. Estimated number (Mean±S.E.) of sensilla chaetica on each antennal segment of adult male and female *D. armigera*.

Segment	Male	Female	t-value
Scape	–	–	–
Pedicel	–	–	–
Flagellum (Fl)			
Fl 1	–	–	–
Fl 2	–	–	–
Fl 3	–	–	–
Fl 4	–	–	–
Fl 5	14.76±0.60[d]	21.35±0.63[d]	-6.33**
Fl 6	36.58±0.61[c]	10.83±0.62[e]	29.58**
Fl 7	37.84±0.58[c]	32.34±0.61[c]	6.05**
Fl 8	42.55±0.66[b]	37.99±0.68[b]	5.45**
Fl 9	119.01±0.79[a]	130.15±0.70[a]	-12.06**
S.Ed. (±)	0.92	0.91	
C.D. $_{0.05}$	1.84	1.82	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Based on morphology, sensilla trichodea (ST) I, ST II, sensilla chaetica (SC), sensilla basiconica (SB) I and coeloconic sensilla were identified in both sexes of the insect. The ST I and II were numerous and observed over the entire length of the antennae whereas SC were observed only on the apical five flagellomeres. In addition, some sensilla suspected to be thermoreceptors (Tr) were also observed on scape, pedicel and some flagellomeres.

The ST I pointed distally and curved towards the antennal shaft. It is a slender structure, which tapers gradually into a very sharp point at the distal end. In males, the lengths of ST I varied from 36.50 ± 0.09 µm to 41.46± 0.03µm. Likewise, their widths varied from 1.74± 0.02 µm to 1.96± 0.01 µm. In female, the lengths varied from 35.21± 0.05 µm 39.52± 0.04 µm and their widths varied from 1.74± 0.02 µm to 1.99± 0.01 µm (Tab. 3). The highest population of ST I was observed on the ninth flagellomere (235± 0.03± 0.69) and the lowest was observed on the scape (2.51± 0.37) in males, whereas in females, the highest population was observed on the eighth flagellomere (204.10± 0.64), and the lowest was observed on the scape (1.88 ± 0.42) (Tab. 4).

The ST II were also similar to ST I except that they were unaffected when a solution of crystal violet was applied. It might be due to non- permeability of the senisilla to crystal violet. In males, the lengths of ST II varied from 24.52±0.06 to 38.11±0.23 µm (Tab. 5). Likewise their widths varied from 1.69±0.01 to 1.87 ± 0.01 µm. In females, their lengths varied from 24.04 ± 0.03 to 36.52 ± 0.05 µm and their widths varied from 1.67±0.01 to 1.80±0.01 µm.

The highest number of ST II was observed on the ninth flagellomere (136.75 ± 0.77) and lowest on the first flagellomere (15.6±0.67) in males. Likewise, in females also the highest number of ST II was observed on the ninth flagellomere (156.84 ± 0.73) and the lowest was observed on the first flagellomere (14.76 ± 0.46) (Tab. 6).

The SC were pointed distally and projected outward from a socket at an approximate angle of 50°, thick-walled and longitudinally grooved. They were restricted to the terminal five flagellomeres and were unaffected when a solution of crystal violet was applied. In males, their lengths varied from 30.15±0.09 to 38.17±0.06 µm (Tab. 7), whereas in females they varied from 32.24 ±0.05 to 38.70± 0.03 µm. In male and female, the highest number of SC was observed on the ninth flagellomere and the lowest was observed on the fifth flagellomere (Tab. 8).

A few sensilla basiconica (SB) were present in different flagellomere of *D. armigera*. SB are smaller than ST measuring 5–6 µm, wall being porous. Pit or coeloconic sensilla are also present on the antennae, however, details of their structure were not studied.

After application of growth regulator, methoprene, some deformities not only on the antennal structure but also on the sensillar morphology were observed; the 4th flagellomere got deformed. This is very prominent on the tip of the ninth flagellomere where SC were observed to be disoriented (Baishya 1992).

DISCUSSION

Densely covered distal segments of the antennae as observed here are also present in many other insects like *Blatella germanica* (Linnaeus, 1767) (Ramaswamy & Gupta 1981, Wheeler & Gupta 1986), *Croesia curvala* (Kearfott, 1907) (Langmaid & Seabrook 1985), *Bootettix argentatus* Bruner, 1890 (Chapman & Fraser 1989), *Geotrupes auratus* Motschulsky, 1858 (Inouchi et al. 1987) and *Homoeosoma electellum* (Hulst, 1887) (Faucheux 1995), and four hemipteran species (Usha Rani & Madhavendra 2005). Palpation conducted with the distal segments of antenna may provide an explanation for this pattern.

On the scape, pedicel and three flagellomeres (first to third), males had significantly greater number of sensilla per unit area than females. However, from the fourth to ninth flagellomere, females had a greater number of sensilla per unit area than males; a similar pattern was reported by Ritcey & McIver (1990) in case of *Psylloides punctulata* and *P. affinis*. A study by Usha Rani & Madhavendra (2005) suggested that sensillae in scape and pedicel may not be used in sensory perception, which remains however to be tested critically.

Similar to *Dicladispa armigera*, terminal segments of antennae covered with ST I and ST II were also reported in *Homoeosoma electellum* (Faucheux 1995), *Phthorimaea operculella* (Zeller, 1873) (Sharaby et al. 2002), *Helicoverpa armigera* (Hübner, 1808) (Wang et al. 2002). Bromely et al. (1980) stated that the ST at the antennal tips of aphids have a contact chemosensory function, and may be involved in gustation of the plant surface, which might be the case in the insect studied here as well.

The population of ST I was highest on the ninth flagellomere in males, whereas in the female it was on the eighth flagellomere. This kind of variation in ST I population may be associated with specific function performed by the sensilla. Similar cases were also recorded in *Trichoplusia ni* (Hübner, 1803) (Mayer et al. 1981), *Grapholitha molesta* (Busck, 1916) (George & Nagy 1984), *Hypera postica* (Gyllenhal, 1813) (Bland 1981). However, in case of both males and females, the ST II population was highest on the ninth flagellomere, which was also reported by Bland (1981) in *Hypera postica*, by Kapoor (1985) in *Paraguetina media* (Walker, 1852) and by Ritcey & McIver (1990) in flea beetles. SC is a common type usually encountered in many insects (Ilango 2000). The presence of SC on antennae was also reported by Ritcey & McIver (1990) in the flea beetles, *P. cruciferae*, *P. punctulata*, *P. affinis* and *E. cucumeris*.

As Hazarika & Baishya (1996) showed, application of methoprene induced morphogenesis in *D. armigera*; however, only the fourth and the last flagellomere were affected. The cause of the selectivity of this effect is unclear up to now. Hormonal regulation of antennal sensilla is reported for many insects (Wheeler & Gupta, 1986; Yamamoto-Kihara et al. 2004). Injection of a neurohormone, [His7]-corazonin, reduced the number of coeloconic sensilla in *Locusta migratoria*. A similar study on *D. armigera* is also required since it could help to clarify the causal network in the development of the antennal sensilla pattern.

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